J. New York Entomol. Soc. 95(4):474–480, 1987

FIELD BEHAVIOR OF *EUPHASIOPTERYX DEPLETA* (DIPTERA: TACHINIDAE): PHONOTACTICALLY ORIENTING PARASITOIDS OF MOLE CRICKETS (ORTHOPTERA: GRYLLOTALPIDAE: *SCAPTERISCUS*)

HAROLD G. FOWLER

Instituto de Biociências, Universidade Estadual Paulista, (UNESP), 13500 Rio Claro, São Paulo, Brazil

Abstract.—Using direct observation and sticky trap captures, larvipositing female *Euphasiopteryx depleta* were studied in central Brazil. Females were attracted by phonotaxis to sound traps that broadcast synthesized calling songs of *Scapteriscus* mole crickets. Mean permanency at sound traps during larviposition was less than 3 secs, with females orienting upwind to sound sources in windy conditions. Data suggest that *E. depleta* populations are highly mobile, with activity periods corresponding to mole cricket calling periods. The number of females attracted to sound traps varied with respect to broadcast sound intensity.

Five species of Scapteriscus mole crickets have been accidentally introduced into the Caribbean and southeastern United States (Nickle and Castner, 1984). Of these species now present in the U.S., *Scapteriscus vicinus* Scudder has been shown to be a significant economic pest (Walker and Ngo Dong, 1982), although the other introduced species are also known to produce unquantified economic damage. Due to the Neotropical distribution of *Scapteriscus*, efforts to identify natural enemies of mole crickets in South America might identify potential biological control agents.

Among the likely control agents for importation into the Caribbean and U.S. are tachinid flies of the genus *Euphasiopteryx*. Wolcott (1940) reported rearing *E. depleta* (Wied) from an unidentified *Scapteriscus* in Belém, Pará, Brazil. In the U.S., the related species *E. brevicornis* (Tocon.) is a parasitoid of *Neoconocephalus robustus* (Scudder) (Nutting, 1963), while *E. ochraceae* (Bigot) has also been attracted to the calling songs of *Gryllus integer* Scudder and to larviposit in their vicinity (Cade, 1975). Mangold (1978) found that *E. ochraceae* was also attracted to the synthesized broadcast calls of *Scapteriscus acletus* Rehn and Hebard, and he was able to rear *E. ochraceae* from this mole cricket under experimental conditions. In Paraguay, *E. depleta* has been attracted to the synthesized broadcast songs of *S. acletus* (Fowler and Kochalka, 1985). Furthermore, *E. depleta* has been reared from three species of field collected *Scapteriscus*, and has been reared from *Scapteriscus* in laboratory experiments (Fowler and Garcia, 1987).

This paper reports on observations of the behavior of *E. depleta* females in the field, as monitored through observations and captures of these phonotactically orienting files at broadcast sound sources. Data on periods of calling activity of mole crickets, and dissections of captured *E. depleta* females, are used to infer further aspects of their biology.

METHODS AND MATERIALS

Most of the observations recorded here were made in Rio Claro, state of São Paulo, Brazil, from July 1984 through July 1986. At one site in Rio Claro (Chacara Betânia),

Table 1. Monthly captures of *E. depleta* females with sticky traps mounted over sound traps broadcasting synthesized songs of *Scapteriscus* mole crickets in Rio Claro, São Paulo, Brazil, during 1985–1986.

Month of year	Number of female *E. depleta* captured at			Total
	S. vicinus	*S. borellii*	*S. imitatus*	
January	97	32	37	166
February	16	8	10	34
March	7	5	4	16
April	0	0	0	0
May	0	0	1	1
June	4	6	1	11
July	2	3	4	9
August	5	3	0	9
September	1	0	0	1
October	21	17	19	57
November	49	22	20	93
December	75	38	47	160
Sum	277	134	143	554

three sound traps (Walker, 1982), broadcasting synthesized calls of *S. borellii* Giglio-Tos (=*S. acletus*), *S. vicinus* Scudder, and *S. imitatus* Nickle and Castner, were run nightly throughout the year. Each sound trap was located 50 m away from its neighbor and covered with a plastic bag coated with Tanglefoot® on which attracted and landing *E. depleta* females were trapped. The locations of each trap were changed daily to minimize the effects of location on the numbers of *E. depleta* trapped. These data were used to determine the relative attractiveness of each species synthesized call to *E. depleta* and to moniter the seasonal abundance of host seeking females.

During periods of peak captures, the landing distribution of *E. depleta* females was determined by plotting their position on sticky traps relative to the center of the sound source. Landing distributions were also ploted during nights with wind velocities of 10 km/hr^{-1} or more, at which time the direction of the wind was recorded. Female *E. depleta* from three nightly catches at *S. borellii* sound traps, and from 13 nightly catches at *S. vicinus* sound traps, were dissected in the laboratory, and the larval complement of each female was recorded.

On the campus of the Universidade Estadual Paulista, approximately 7 km distant from the first site, another series of field observations was undertaken. During peak activity (December 1984–January 1985), taped synthesized calls of *S. vicinus*, *S. imitatus*, *S. borellii*, *S. didactilus* Scudder, and *Neocurtilla hexadactyla* Perty were simultaneously broadcast during 10 non-consecutive nights, and the number of *E. depleta* trapped on sticky plastic bags was recorded. During the remaining 50 days, 2 sound traps broadcasting *S. vicinus* synthesized songs and 2 sound traps broadcasting *S. borellii* synthesized songs were used daily. Sound traps broadcast approximately 100 db at full intensity. One of the sound traps broadcasting the call of each species was run at this intensity while the other broadcast at ¼ full intensity (Watts) as measured by a potentiometer. As before, the locations of each of the 4 traps were changed each night. Female *E. depleta* were captured with sticky traps as before, and

Table 2. The effects of sound intensity of broadcast synthesized calls of *Scapteriscus* mole crickets on the capture of female *E. depleta* (paired tests).

Synthesized *Scapteriscus* broadcast call	Broadcast call intensity (Watts)	Number of *E. depleta* captured	G	*P*
S. borellii	full	51		
	¼	19	81.85	<0.05
S. vicinus	full	121		
	¼	62	234.32	<0.05

their temporal activity was monitored by recording catches every 30 min. These data were than compared with the flight activity data of *S. vicinus* (A. Silveira-Guido, unpubl.).

RESULTS

Seasonal activity of female *E. depleta* was found to be largely concentrated in the late spring and early summer (Table 1). A significant seasonal variation was found for captures at all sound traps ($G = 777.39$; $P < 0.05$; $df = 22$), but the seasonal distribution of catches was not found to differ significantly between sound sources, using the log-likelihood G statistic (Zar, 1974), for pairwise species comparisions taken month by month (36 comparisons). Based on these captures, the song of *S. vicinus* was approximately twice as attractive to phonotactically orienting *E. depleta* females than either *S. imitatus* or *S. borellii* (Table 1). This result, using total annual capture, was significant ($G = 65.544$; $P < 0.05$).

In the 10 day test using taped synthesized songs, the number of *E. depleta* captured at each broadcast call was 0 for *S. didactylus* and *N. hexadactyla*, 24 for *S. borellii*, 33 for *S. imitatus*, and 51 for *S. vicinus*.

In evaluations of the effect of sound intensity on the number of *E. depleta* attracted (Table 2), full intensity attracted significantly more flies than did ¼ full intensity, for both *S. vicinus* and *S. borellii* broadcast calls ($P < 0.05$).

Using a sound trap broadcasting *S. vicinus* synthesized male calls and a weak red light and digital stopwatch, 20 female *E. depleta* were timed for permanency at the sound. All females arrived and left the sound source in 3 secs or less. During this time, they quickly circled the point source while depositing larvae.

The landing distribution of larvipositing females is shown in Figure 1. During non-windy nights, no significant directionality of landings was observed (Fig. 1), but directionality was significantly downwind during windy nights, using Raleigh's test (Zar, 1974) ($P < 0.05$). A strong unimodal peak of landings was detected 10 to 15 cm from the point sound source, with the resulting landing distribution conforming to a Poisson, using a goodness of fit test (Zar, 1984).

The mean and variance of larval numbers of female *E. depleta* caught during 3 nights at the *S. borellii* sound source was 148.2 and 90.20 respectively (range 32–400, $N = 30$ females), while for the 13 nightly catches at *S. vicinus* sound sources, the mean was 175.5 and the variance 90.96 (range 28–488, $N = 111$ females). The daily means and variances were weakly correlated ($r = 0.63$) (Fig. 2). In all cases, the variance was smaller than the mean (Fig. 2).

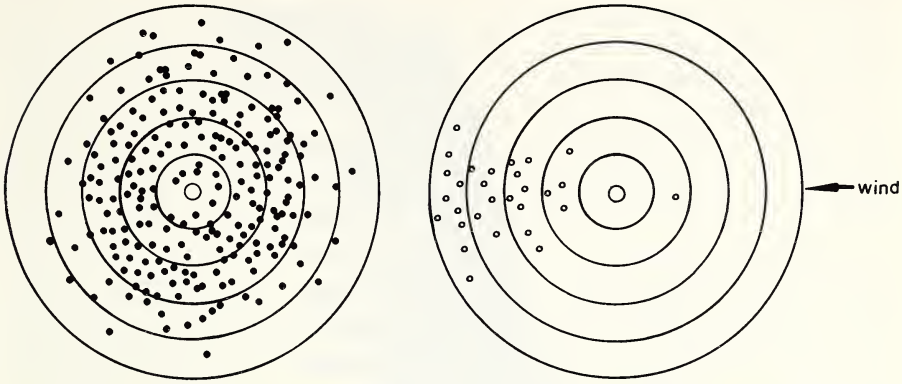

Fig. 1. The landing distributions of female *E. depleta* on sticky traps mounted over sound traps. Each annulus corresponds to 5 cm, with the sound source centered. Distributions of landing females are compared on windy and non-windy nights.

By comparing the flight periods of *S. vicinus* (Fig. 3) with the temporal pattterning of captures of *E. depleta* females (Table 3), the proportion of flies captured during mole-cricket flight periods was only 44.3%. However, males call for at least 1.5 hrs after sunset, but much less, and this gives a synchrony of 67.8%.

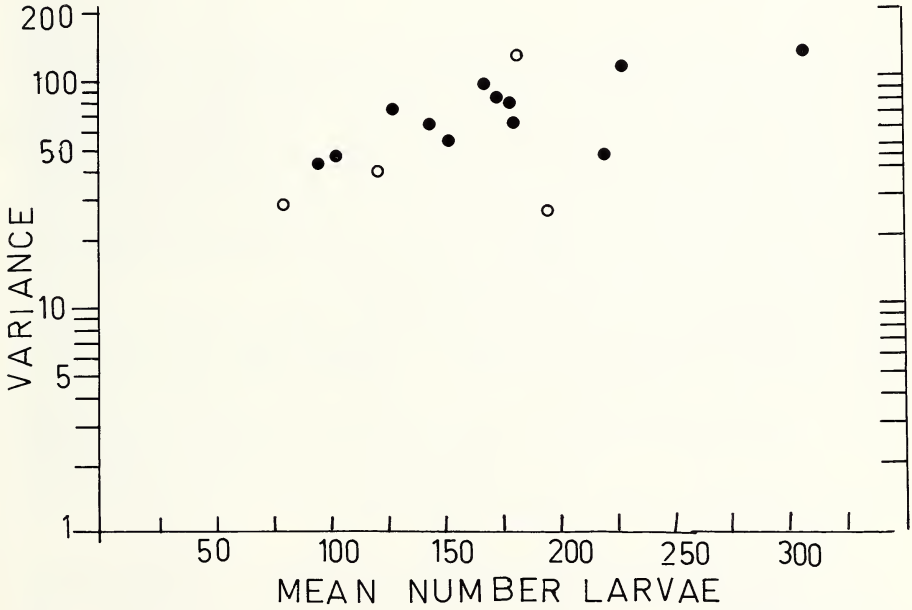

Fig. 2. The mean-variance relation of the number of larvae present in female *E. depleta* on separate capture nights. Open circles = *S. borellii* sound trap, closed circles = *S. vicinus* sound traps.

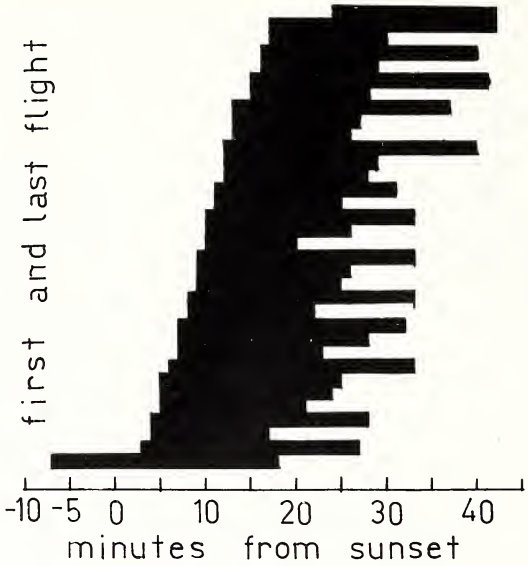

Fig. 3. The timing of first and last flights of *S. vicinus* in Santana do Livramento, Rio Grande do Sul, Brazil. Data furnished by Aquiles Silveira-Guido. Each bar represents one night of observation.

DISCUSSION

The results of these observations clarify the potential usefulness of *E. depleta* as a potential candidate for introduction in biological control programs for *Scapteriscus* mole crickets. Large numbers of flies were attracted to the songs of *S. vicinus*, *S. borellii*, and *S. imitatus*, all of which are exotic pests in the Caribbean and southern United States. During this study, no flies were attracted to the synthesized calls of *S. didactylus*, also introduced accidentally into the Caribbean (Nickle and Castner, 1984), nor to the calls of *N. hexadactyla*, a native mole cricket in North and South America. The higher relative preference shown for *S. vicinus* calls is supported by earlier work (Fowler, 1987a; Fowler and Garcia, 1987).

The seasonal activity of *E. depleta* documented by sticky trap captures at sound traps coincides with the seasonal occurrence of dispersal flights in South American *Scapteriscus* (Fowler, 1987b). That *E. depleta* can be captured at other periods, but

Table 3. The number of *E. depleta* captured at sound traps as a function of time of capture.

Hours from sunset	Number of *E. depleta* captured	Proportion of total
0–0.5	17	0.093
0.5–1.0	64	0.350
1.0–1.5	43	0.235
1.5–2.0	27	0.147
2.0–2.5	9	0.049
2.5	23	0.126
Total	183	1.000

in much lower numbers, suggests that alternative hosts might exist. In fact, *E. depleta* has been reared from field collected *Anurogryllus* sp. (Fowler and Mesa, 1987), as well as from *Scapteriscus abbreviatus* Scudder, a brachypterous species which does not call (Fowler and Garcia, 1987). Moreover, *E. depleta* is an established phonotactically orienting parasitoid of *S. vicinus* (Fowler and Garcia, 1987; Fowler, 1987a, b), and other possibilities could explain field patterns of activity. The diel synchrony of *E. depleta* phonotaxis and *S. vicinus* flight activity adds further support to the role of *E. depleta* as an ideal biological control candidate.

The relatively rapid larvipositional runs of *E. depleta* females at sound traps, as well as the differential response to varying sound intensity, are of special importance. Louder calling male *Scapteriscus* mole crickets have been shown to attract a larger number of dispersing females to their burrows (Forrest, 1980, 1983), and thus would attract greater numbers of *E. depleta* as well. Female mole crickets enter male calling burrows for mating (Forrest, 1980), and by larvipositing at an annulus 10–15 cm from the burrow opening, *E. depleta* larvae would be ideally placed to attach themselves to attracted female mole crickets. It has been shown that this behavior could have a large impact on the mate selection processes in mole crickets (Fowler, 1987d). Male mole crickets could respond by calling in a more discontinuous manner, but even this does not deter the phonotactic ability of female *E. depleta* (Fowler, 1987c).

If sound traps capture all receptive females in a given area, then the normal distribution of the number of larvae per attracted female *E. depleta*, suggests that females are reproductively active over many days and that they are highly mobile. As sound traps fitted with sticky traps have the potential of indeed attracting and capturing all *E. depleta* females within a given area, all resulting catches should demonstrate a very high mean, near 500, and a very small variance, unless new flies were continuously entering the area. Older females, with a lower number of larvae, could only be trapped if they immigrated into the area. This power of dispersion is an additional attribute of *E. depleta*, and suggests that it could track mole cricket populations in the field, and could behaviorally respond to these populations.

Much more needs to be learned about *E. depleta*. For example, nothing is known about male behavior, as males are not attracted to sound sources. Nor is the behavior of females during the day yet known. Further, difficulties have been found in obtaining reproductive maturity in the laboratory with experimentally reared females (Fowler, 1987a). All of these indicate that we still lack a complete understanding of the reproductive behavior and ecology of *E. depleta*. None of these factors, however, lessen the usefulness of *E. depleta* as a potential introduction to control exotic populations of *Scapteriscus* mole crickets. They only indicate that much more research needs to be performed to eliminate these and other impediments for their management and use in biological control programs.

ACKNOWLEDGMENTS

I gratefully thank Bianca Saes for assistance with the field observations and my technician Maria Teresa Vieira de Camargo for assistance with larval dissections and counts. This study was partially supported by a grant, USDA No. 83-CRSR-2-2162. I thank T. J. Walker and J. H. Frank from the University of Florida and two anonymous reviewers for their helpful comments which have served to greatly improve this manuscript. Florida Agricultural Experiment Station journal series no. 7983.

LITERATURE CITED

Cade, W. 1975. Acoustically orienting parasitoids: fly phonotaxis to cricket song. Science 190: 1312–1313.

Forrest, T. G. 1980. Phonotaxis in mole crickets: its reproductive significance. Fla. Entomol. 63:45–53.

Forrest, T. G. 1983. Calling songs and mate choice in mole crickets. Pages 185–204 *in*: Gwynne, D. T. and G. K. Morris (eds.), Orthopteran Mating Systems: Sexual Competition in a Diverse Group of Insects. Westview Press, Boulder, Colorado.

Fowler, H. G. 1987a. Suitability of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae) as hosts of *Euphasiopteryx depleta* (Diptera: Tachinidae). Entomophaga. (in press).

Fowler, H. G. 1987b. Geographic variation in the flight periodicity of New World mole crickets. J. Interdiscipl. Cycle Res. (in press).

Fowler, H. G. 1987c. Direct field confirmation of the phonotaxis of *Euphasiopteryx depleta* (Diptera: Tachinidae) to calling males of *Scapteriscus vicinus* (Orthoptera: Gryllotalpidae). Fla. Entomol. (in press).

Fowler, H. G. 1987d. A seleção sexual e o parasitismo: *Euphasiopteryx depleta* (Diptera: Tachinidae) e *Scapteriscus vicinus* (Orthoptera: Gryllotalpidae). Cien. Cultura. (in press).

Fowler, H. G. and C. R. Garcia. 1987. Attraction to synthesized songs and experimental and natural parasitism of *Scapteriscus* mole crickets (Orthoptera: Gryllotalpidae) by *Euphasiopteryx depleta* (Diptera: Tachinidae). Rev. Bras. Biol. (in press).

Fowler, H. G. and J. N. Kochalka. 1985. New record of *Euphasiopteryx depleta* (Diptera: Tachinidae) from Paraguay: attraction to broadcast calls of *Scapteriscus acletus* (Orthoptera: Gryllotalpidae). Fla. Entomol. 68:225–226.

Fowler, H. G. and A. Mesa. 1987. Alternative Orthopteran host (*Gryllus* sp. and *Anurogryllus* sp.) of *Euphasiopteryx depleta* (Diptera: Tachinidae). Fla. Entomol. (in press).

Mangold, J. R. 1978. Attraction of *Euphasiopteryx ochraceae*, *Corethrella* sp. and gryllids to broadcast calls of the southern mole cricket. Fla. Entomol. 61:56–61.

Nickle, D. A. and J. L. Castner. 1984. Introduced species of mole crickets in the United States, Puerto Rico, and the Virgin Islands (Orthoptera: Gryllotalpidae). Ann. Entomol. Soc. Am. 77:450–465.

Nutting, W. L. 1953. The biology of *Euphasiopteryx brevicornis* (Townsend) (Diptera, Tachinidae), parasitic in the cone-headed grasshoppers (Orthoptera, Copiphorinae). Psyche. 60:69–81.

Walker, T. J. 1982. Sound traps for sampling mole cricket flights (Orthoptera: Gryllotalpidae: Scapteriscus). Fla. Entomol. 65:105–110.

Walker, T. J. and Ngo Dong. 1982. Mole crickets and pasture grass: damage by *Scapteriscus vicinus*, but not by *S. acletus*. Fla. Entomol. 65:300–306.

Wolcott, G. N. 1940. A tachinid parasite of Puerto Rican changa. J. Econ. Entomol. 33:202.

Zar, J. H. 1974. Biostatistical Analysis. Prentice and Hall, Englewood Cliffs, New Jersey.

Received January 28, 1987; accepted July 22, 1987.